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Ecological scarcity 2013—new features and its application in industry and administration—54th LCA forum, Ittigen/Berne, Switzerland, December 5, 2013

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Abstract The 54th LCA forum was held on December 5, 2013 to launch the fourth generation ecological scarcity method, applied to Switzerland. This conference report presents the highlights of the LCA forum. The ecological scarcity method belongs to the family of distance-to-target methods and is based on politically and legally defined environmental goals. The application of the method in industry and politics as well as its benefits, the main elements of the method and new elements such as the assessment of abiotic resources, global land use, noise and nuclear waste are presented. The losses (and not the extraction) of abiotic resources are characterised with the abiotic depletion potential. Land use impacts on flora and fauna biodiversity are quantified per land use type and for 14 different biomes. Transport noise is assessed based on the number of highly annoyed persons. Finally, nuclear waste is characterised using the radio toxicity index, a parameter commonly used in the nuclear industry. In three policy-making areas, LCA in general and the ecological scarcity method in particular are being applied: waste policy, biofuels tax exemption and Green Economy. Practical applications in administration and industry show that the eco-factors are considered useful in decision making because they cover a broad range of environmental impacts aggregated to a single score. The results of first applications and comparisons showed that the switch from third to fourth generation eco-factors hardly affects the results and conclusions although there are some significant changes in the eco-factor of individual pollutants. It was concluded that the fourth generation is a moderate evolution from the third generation published in 2008. It is considered crucial to allow for single-score methods as they allow to assess environmental impacts comprehensively and to identify environmental hot spots. The method presented thus is suited for a "true and fair" reporting on environmental information.

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1 Introduction and overview

Distance-to-target methods are one of the main families of life cycle impact assessment methods. They are based on politically and legally defined environmental goals. For example, the ecological scarcity approach, first introduced in 1990, has evolved into an important pillar of environmental policy in administration and industry. The fourth generation ecological scarcity method, applied to Switzerland, was launched during the 54th LCA forum on December 5, 2013 (Frischknecht and Büsser Knöpfel 2013).

In the first session of the LCA forum, the application of the ecological scarcity approach and its benefits in legislation and environmental monitoring in administration were highlighted. In a second session, the main elements of the fourth generation ecological scarcity method 2013 were presented. New elements of the method comprise, amongst others, abiotic resources, land use worldwide, noise and a new approach to assess nuclear waste. The results of practical applications (paper, beverage packaging, buildings, an optical lens manufacturer and a retailer) using the new eco-factors were presented in the afternoon sessions.

This 54th LCA forum addressed the following questions:

- What are the key motivations for administration and industry to use single-score impact assessment approaches such as the ecological scarcity method?
- What are the key elements of the fourth generation ecological scarcity method 2013?
- How does the update affect the impact scores (in eco-points) of commonly used goods and services?

- What are the first lessons learned with the updated fourth generation ecological scarcity method 2013?
- How does division of powers help develop life cycle impact assessment methods?

2 The users' perspective: ecological scarcity method applied in administration

The 54th LCA forum was opened with welcome addresses given by Anders Gautschi (FOEN) and Gabi Hildesheimer (ÖBU) emphasising the role of life cycle assessment in general and the ecological scarcity method in particular to help greening the economy. Arthur Braunschweig (E2 Management Consulting) gave a short introduction of the ecological scarcity method and its historical development. In the late 1980s, an environmental assessment method was developed by Ahbe et al. (1990) that allowed for single-score results, are based general and neutral definition of "environment", have the support of the governmental environmental authority and soundly reflect the scientific understanding of environment and its protection. With the help of this method, the structure of the results of product alternative comparisons as well as priority setting in the environmental management of companies became very useful for further internal discussion.

Anders Gautschi (FOEN) presented the use of the ecological scarcity method in policy making in view of greening the economy. He mentioned three policy-making areas where LCA in general and the ecological scarcity method in particular are being applied: waste policy, biofuels tax exemption (MinöStV 2014, article 19) and Green Economy. One of the four main areas of the action plan for Green Economy (BAFU 2013) covers measurement and information, where LCA plays an important role (e.g. a voluntary scheme for environmental product information [1]). According to him, the ecological scarcity method and its Swiss implementation shows the following five advantages:

- *single score*: a clear answer to complex questions.
- Based on *politically and legally defined environmental goals*→representative for Swiss policy objectives.
- *Comprehensive* range of environmental indicators are included→complete picture.
- *Transparent weighting*, independent of particular interests.
- *Regionalisation* for water scarcity and biodiversity allows comparison of Swiss and foreign products.

[1] Mandatory regulations will only be implemented in accordance with international regulations (European Union).

Daniel Peter (Peter Sustainability Consulting Ltd.) showed how LCA and the ecological scarcity method are being applied in the Resources and Environmental Management of the Swiss Federal Administration (called RUMBA). The environmental management system covers all seven Federal Departments and the Federal Chancellery. It covers 50 units with about 17,000 full-time equivalents (FTE). The work results in 50 eco-balances of the units, seven eco-balances of the Federal Departments and one overall eco-balance of the Federal Administration. The Federal Administration intends to reduce the environmental impacts by 10 % per FTE until 2016. This target was already achieved in 2011 (excluding CO_2-offsets) and 2010 (including CO_2-offsets), respectively. The eco-balances cover energy demand (heat and electricity), water and paper consumption, business travel and waste water and waste generated. The results of the eco-balances are displayed in time series to monitor the development over time, and they are compared amongst the seven Federal Departments. The Swiss eco-factors of the ecological scarcity method are used because of their high practicability, their single-score results (which makes it easier for leaders of environmental teams to understand), because they facilitate the planning of measures and because the effects of the implementation of measures are easily quantified or estimated.

3 The fourth generation ecological scarcity method 2013

Rolf Frischknecht (treeze Ltd.) presented the overview and the main elements of the fourth generation of Swiss eco-factors according to the ecological scarcity method. The goal of the project was to update the Swiss eco-factors 2006 by tracking the Swiss environmental situation and the Swiss environmental legislation. Ways should be explored to include new and emerging environmental topics. The project resulted in mainly two deliverables: new and updated Swiss eco-factors 2013 and a methodology applicable in other regions or countries. After presenting the organisation and the phases of the 2-year project, the new elements of the final report were highlighted, including a section targeted to decision makers and to an audience learning the basics of life cycle assessment. He then explained the basic scarcity formula which forms the backbone of the ecological scarcity method:

For every environmental impact, the eco-factor is defined as follows:

$$\text{Eco-factor} = \underbrace{K}_{\substack{\text{Characterization}\\(\text{if applicable})}} \cdot \underbrace{\frac{1\cdot \text{EP}}{F_n}}_{\text{Normalization}} \cdot \underbrace{\left(\frac{F}{F_k}\right)^2}_{\text{Weighting}} \cdot \underbrace{c}_{\text{constant}} \qquad (1)$$

with:

K	Characterisation factor of a pollutant or of a resource (if applicable)
Flow	Load of a pollutant, quantity of a resource consumed or level of a characterised environmental pressure
F_n	Normalisation flow: current annual flow in the country for which the method is applied
F	Current flow: current annual flow in the reference area
F_k	Critical flow: critical annual flow in the reference area
c	Constant (10^{12}/a)
EP	Eco-point, the unit of the assessed result

This formula allows for regionalised eco-factors by applying it as follows:

$$\text{Eco-factor}^{\text{Region 1}} = K \cdot \frac{1 \cdot EP}{F_n^{\text{REF}}} \cdot \left(\frac{F^{\text{Region 1}}}{F_k^{\text{Region 1}}} \right)^2 \cdot c \qquad (2)$$

with:

K	Characterisation factor of a pollutant or a resource (if applicable)
Flow	Load of a pollutant, quantity of a resource consumed or level of a characterised environmental pressure
F_n^{REF}	Normalisation flow: current annual flow within the reference area
F^{Region1}	Current flow: current annual flow with Region 1 as the system boundary
F_k^{Region1}	Critical flow: critical annual flow with Region 1 as the system boundary
c	Constant (10^{12}/a)
EP	Eco-point, the unit of the assessed result

Equation (2) corresponds to Eq. (1) if Region 1 is identical to the reference region.

The fourth generation Swiss eco-factors based on the ecological scarcity method introduce several new features (see general outline in Fig. 1). A new characterisation approach was developed for nuclear waste. The radiotoxicity index (RTI) quantifies the ionising impact of the isotopes present in the different nuclear wastes. Low- and medium-active wastes show much lower characterisation factors compared to alpha toxic wastes and high-active wastes and spent fuel (see Table 1).

The relative importance of the different environmental impacts and topics changed over time. The importance of climate change increased steadily and now reaches a share of about 25 % of the Swiss environmental impacts whereas ozone depletion and non nuclear wastes dropped substantially. Air and water qualities are still important. Land use, energy and water resources and noise are newly emerging impacts. Overall, a cut by about 50 % of the current Swiss environmental impacts quantified with the Swiss eco-factors of the ecological scarcity method 2013 is required to fulfil the Swiss legal environmental targets.

Sybille Buesser Knoepfel (treeze Ltd.) focused in her talk on three new elements of the eco-factors 2013 of the ecological scarcity method, namely global land use, noise and abiotic resources. The existing approach on land use was updated with new figures and new characterisation factors based on the work of de Baan et al. (2012). The new eco-factors cover global land use types. Based on the concept of biomes (Olson et al. 2001), regionalized land use impacts can be assessed which is relevant with regard to goods harvested or manufactured in areas with high biodiversity. The assessment of traffic noise is newly introduced into the ecological scarcity method. Eco-factors for noise caused by road, rail and air freight and passenger transportation are offered. These new eco-factors have an impact of between 5 and 20 % on road and rail transportation, whereas the impact with regard to air transportation is marginal. Eco-factors for mineral and metal resources are newly introduced. The characterisation factors are based on the abiotic depletion approach introduced by Guinée et al. (2001), where production and reserve figures have been updated using the most recent statistical data (USGS 2011). The political target refers to closing material cycles. It is recommended to assess the amount of dissipatively used resources (they are considered lost and hardly available for future use) rather than the amount extracted. The remaining portion, which can be recovered or recycled, is considered "on loan" and is available for future use. This approach is comparable to the assessment of the consumptive use of water (see e.g. Kounina et al. 2013).

Carla Aparecida Ng (ETH Zürich) presented the approach of assessing the environmental impacts of persistent organic pollutants emitted to water using the bioconcentration factor (BCF) as a reliable and readily available proxy. The bioconcentration factor of a chemical relates the concentration observed in organisms (fish) to the concentration of the surrounding environment (water bodies). BCF is a robust hazard metric because it is linked to physicochemical properties and it is a relevant metric because of its use in the European REACH regulation. The Swiss eco-factors 2013 cover emissions of plastic additives, PCBs, PFCs, PBDEs, PFASs, PAHs and HFCs. The reference substance used in characterisation is 2,4,6-tribromophenol because of its rather average BCF and its quantitative importance. In total, more than 200 bioaccumulating substances are characterised with this new approach.

4 Application of ecological scarcity 2013 in industry

The afternoon session was opened by Emil Franov (CARBOTECH) who presented an LCA case study about recycled paper. He compared the results using the third

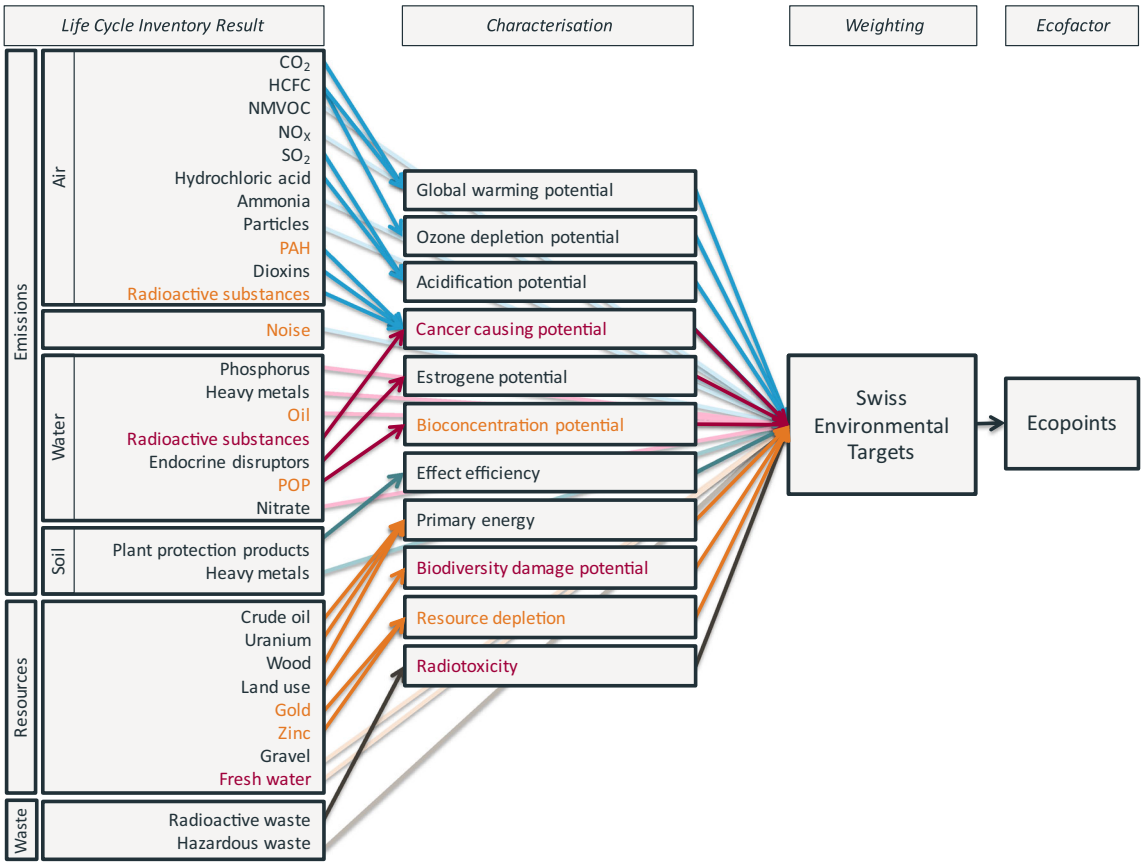

Fig. 1 Basic diagram of the method including the characterisation and weighting steps

generation eco-factors with those using the new, fourth generation eco-factors. He concluded that the results do not change when using the new eco-factors, although there are some significant changes in the eco-factor of individual pollutants. A recycled paper of Antalis shows an environmental footprint lower than that of all other recycled and virgin papers analysed. Such information is used in communication at Antalis.

Hanna Krayer (Migros) showed how sustainability concepts are implemented in daily practice of the largest Swiss retailers. Life cycle assessment is mainly used in optimising packaging and in developing packaging guidelines. Migros faces methodological challenges regarding good and reliable generic process data, environmental crediting (recycling) and the effects of labelled products and packaging (FCS, organic). Migros considers the Swiss eco-factors to be too complex for their customers (consumers) and thus does not use it in marketing. However, they are applied internally for decision making because it considers various environmental impacts and because it is an understandable single-score method.

Fredy Dinkel (CARBOTECH) presented the preliminary results of a comparative LCA of beverage containers commissioned by the Swiss Federal Office for the Environment. The results are not yet for (printed) publication.

Arthur Braunschweig (E2 Management Consulting) presented his thoughts on using ecological scarcity in companies based on the experiences with McDonalds (Switzerland) and other companies. He identified several situations where LCA is a suitable tool from an organisation's point of view. Highlighting the need for clear messages with regard to

Table 1 Characterisation factors of the different categories of nuclear wastes

	Radiotoxicity index (RTI) m^{-3}	Characterisation factor m^3 HAA-eq/m^3
Low- and medium- active waste	4.1×10^7	0.000045
Alpha toxic waste	1.4×10^9	0.00015
High- active waste (HAA, including spent fuel)	9.3×10^{11}	1
High- active and alpha toxic waste[a]	7.1×10^{11}	0.76

[a] Inventory flow of ecoinvent data v2.2

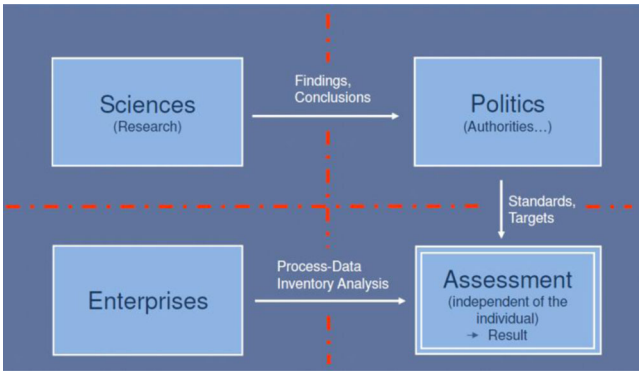

Fig. 2 A basic principle for environmental assessments: "separation of powers" to avoid arbitrariness (Ahbe 2013)

environmental impacts, the two alternatives are the following: either single score or single issue (e.g. climate change). The development of the environmental impacts of McDonalds (Switzerland) and the product LCA of Canon printers were used to show the usefulness of single-score impact assessment methods. In both cases, the hot spots were easily identifiable and measures to improve the environmental performance of McDonalds (Switzerland) and Canon printers were taken.

Fredy Dinkel (CARBOTECH) showed the results of an LCA of optical lenses produced by Knecht & Müller, a Swiss company. Silica lenses cause less environmental impacts compared to plastic lenses. The decision of the company to purchase green-certified electricity lowers the environmental impacts of manufacturing lenses by 60 to 70 %. The switch from third to fourth generation eco-factors hardly affects the results; thus, the past findings and conclusions are confirmed.

Viola John (ETH Zürich) assessed the environmental impacts of construction, operation and dismantling of 12 Swiss apartment buildings of different sizes (from two to more than 100 apartments with a floor area from 350 m^2 to more than 20,000 m^2). The environmental impacts per square metre energy surface area, quantified with the ecological scarcity method, are compared to the greenhouse gas emissions and the non renewable energy demand per square metre energy surface area to identify similarities and discrepancies. Furthermore, a comparison of the environmental impacts using the third and the fourth generation Swiss eco-factors revealed only small differences.

Ulrich Kral (TU Vienna) presented the results of a study to develop regionalised eco-factors for heavy metals using the case of copper. The weighting factors for copper flows in Vienna differ substantially (higher by a factor of 10 to 20) from the ones of the Swiss eco-factors 2006. He emphasised that the eco-factors vary depending on the reference region and the spatial resolution within the region. He suggested working on a harmonised framework for regionalised eco-factors.

Sébastien Humbert (QUANTIS INTERNATIONAL) presented an LCA case study on fossil power production in Belgium, which illustrates the use of the regionalised eco-factors for water use, which are recommended by the European Commission. He presented results using the eco-factors based on the ecological scarcity method and compared them with results using other water footprint assessment methods. The assessment results using Pfister et al. 2009 are similar to the results using the water indicator of the ecological scarcity method.

5 Plenary discussion

Stephan Ahbe (SYRCON ECONOMIC ENGINEERS) presented his idea of the "separation of powers" to avoid arbitrariness in environmental assessments (see Fig. 2). The environmental assessment of products, processes and companies is done independent of the development of the impact assessment method. The latter is derived from or authorised by politics (authorities). Politics rely on the scientific knowledge, findings and conclusions. The enterprises provide the process data and may carry out the inventory analysis. According to Stephan Ahbe, the ecological scarcity method complies best with the requirement of "separation of powers".

Peter Gerber (FOEN) and Gabi Hildesheimer (ÖBU) closed the day by thanking all the presenters, the organisers of the event and the audience both present in the room and online.

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